



DOE's Critical Materials Strategy



Diana Bauer
US Department of Energy
Office of Policy and International Affairs
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Motivation

- The global deployment of energy efficiency and renewable energy technologies implies an increased demand for rare earth elements and other materials.
- This is one of the many challenges we face in advancing a clean energy agenda.
- The Strategy is one step towards addressing this challenge.


Approach to Address the Challenge

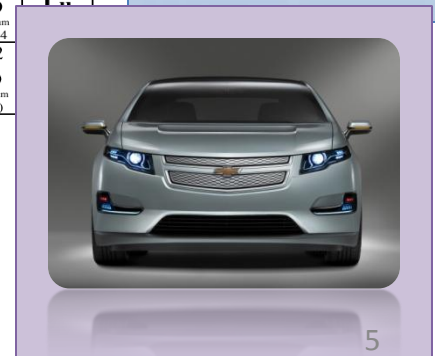
- Supply chain globalization
- Material substitution in clean energy applications
- Recycling, re-use, and more efficient use

Strategy Scope

- Material demand for 4 energy technologies:
 - Wind turbines: magnets
 - Electric vehicles: batteries, magnets
 - Solar cells: PV films
 - Energy efficient lighting: phosphors
- Energy Deployment Scenarios
 - Moderate Deployment: IEA Baseline, Reference
 - Rapid Deployment: IEA Blue Map, 450 Scenario
- Challenges and opportunities in the short and medium term

Priority Elements

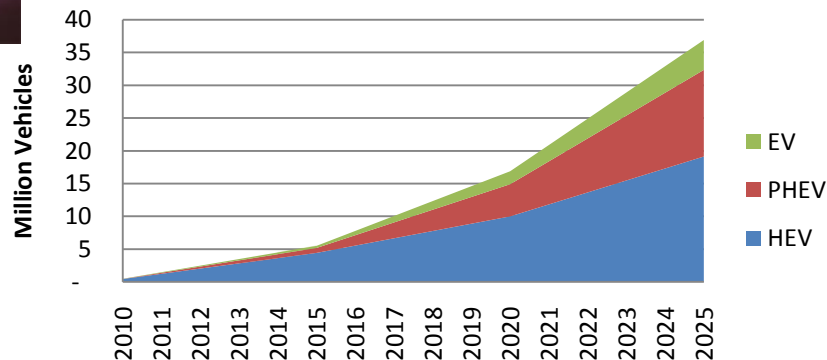
1 H Hydrogen 1.00794																	2 He Helium 4.003														
3 Li Lithium 6.941	4 Be Beryllium 9.012182																	5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797								
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050																	13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948								
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80														
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29														
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)														
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114																		
																		58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
																		90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	



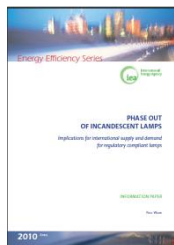
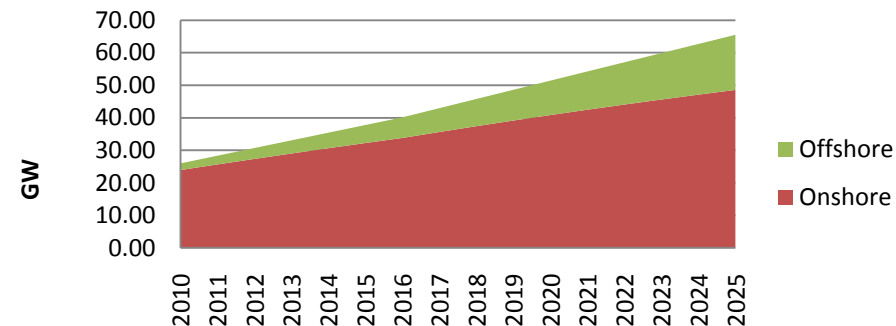
Technology High Deployment Scenarios



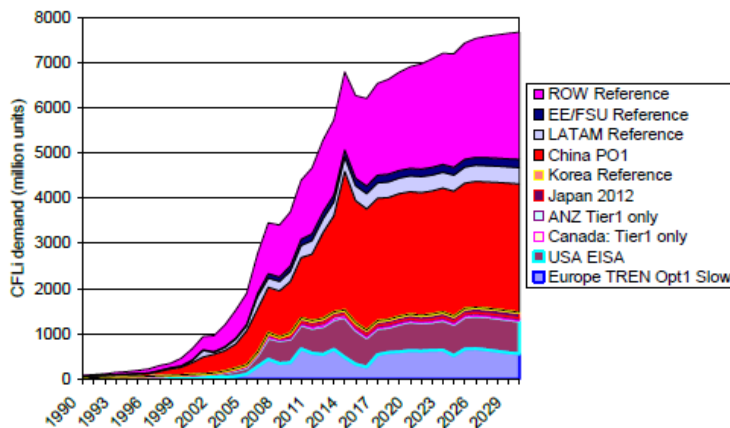
Additions of Hybrid and Electric Vehicles



Wind Additions

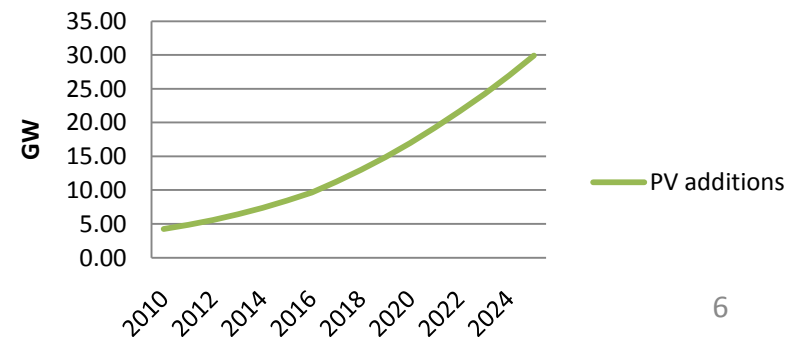


Global CFL Demand



Source: IEA estimated.

Global PV Additions



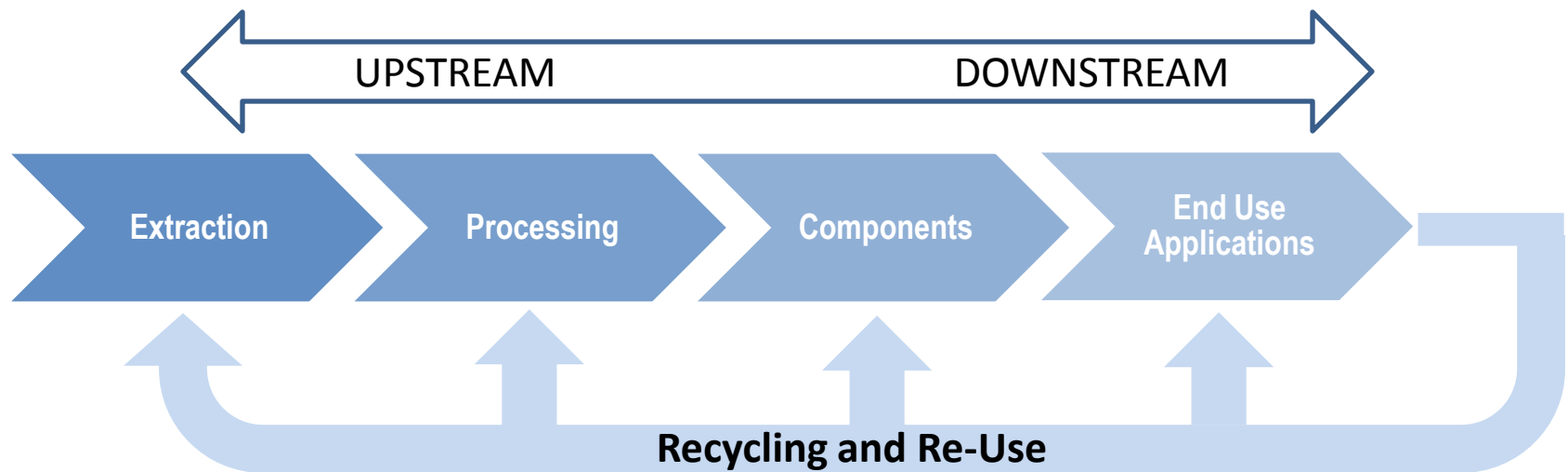
Project Timeline

TO DATE

- March 17 – Assistant Secretary Sandalow announces plan to develop DOE's Critical Materials Strategy
- May 6 – Request for Information (RFI) released
- June 7 – RFI closed
- June- present – Analysis and drafting

Report will be available later this year

The Strategy is Addressing the Entire Supply Chain



Factors Complicating Materials Markets

- Large mining capital requirements
- Material coproduction
- Bottlenecks and lag times across the supply chain
- Price volatility
- Lack of market transparency
- Geopolitical aspects of mining and manufacturing
- Uncertain future demand profiles

Topics Explored in Connection with the Strategy

- Information
- Financial Incentives
- R&D
- Education and Training

Related Government Activities

- GAO Report: Rare Earth Materials in the Defense Supply Chain
- CRS Report: Rare Earth Elements: The Global Supply Chain
- DOD – Forthcoming study identifying defense applications of rare earths
- OSTP– Rare Earth Elements Interagency Workgroup

Rare Earth/ Critical Materials R&D Needs Workshops

- Nov 18-19 Japan-US REE Roundtable at LLNL
- Dec 3 Transatlantic Workshop on Rare Earth Elements and Other Critical Materials for a Clean Energy Future at MIT
- Dec 6 ARPA-E Workshop on Rare Earth and Critical materials

U.S.-Japan REE Roundtable

- DOE, national laboratories, USGS, academia, business/industry
- Japan delegation led by Toru Nakayama, NEDO
 - New Energy and Industrial Technology and Development Organization (NEDO)
 - National Institute of Advanced Industrial Science and Technology (AIST)
 - Japan Oil, Gas and Metals National Corporation (JOGMEC)
 - Agency for Natural Resources and Energy, METI
 - Tohoku University
 - Kansai University

U.S.-Japan REE Roundtable : R&D Topics Discussed

I. Fundamental Properties of Rare Earths

- Fundamental coordination chemistry of f-element materials
- Multiple scales: nano- to micro- to bulk
- Behavior and performance in various molecular structures and complexes

II. Detection, Recovery, and Separation

- Detection and Extraction
 - Remote sensing and geochemical exploration to detect and characterize concealed ore deposits
 - Target extraction with selective solvents
- Element Separations
 - Increase separation factors among elements
 - Apply to both mined materials and recycle streams
 - E.g. advanced ion exchange, solvent extraction, electrochemical
- Simple, economic, energy-efficient, with low environmental impact

III. Physical Characterization and Models

- Applies to Rare Earth Elements and potential substitutes
- Characterization methods and technologies
 - Rapid techniques for quantitative automated mineralogy
 - Assay bulk material, no preparation, non-destructive, near real-time
- Computational science, models, and simulation
 - Improve approximation methods for modeling f-electron atoms
 - Explore methods from atomistic to multi-scale or multi-physics simulations
 - Material property-based design tools
- Tune properties in rapid, non-destructive, economical way

IV. Effectiveness of Use in Targeted Applications

- Japan's Rare Metal Substitute Materials Development Program – Target Applications in Rare Earths
 - **Dysprosium** and **Neodymium** for REE magnets [30% reduction]
 - Grain refinement and nanostructure techniques
 - REE- less/free alloys or other elements
 - **Cerium** for polishing abrasives [30% reduction]
 - Composite abrasive technology
 - Cerium-free abrasives with reformative polishing techniques
 - **Europium** and **Terbium** in phosphors for fluorescent lighting [80% reduction]
 - Optimized use in manufacturing and lighting systems
 - Materials development in glasses and phosphors

Other Areas for U.S.-Japan Cooperation

- Platforms for exchange of information and ideas
 - Virtual data bases and networks
 - Research results, tools, methods, lessons learned, best practices
- Human capital development
 - Education and training for new and transitional professionals
 - Develop market cohorts: business, economics, legal, political, socio-environmental
- Lifecycle and strategic risk management studies
 - Strategies for sustainability and R&D activities
 - Evaluate regional and global market developments

Questions?

<http://www.pi.energy.gov/>

diana.bauer@hq.doe.gov